ADAPTIVE SOLUTIONS FOR OPTIMIZING TRANSPORTATION NETWORKS

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

by

Rishita Mishra

Registration No. – MRUMADN012K220058

Under the supervision of

Dr. Bhawna Singla

Assistant Professor

(Mathematics)

Department of Sciences

School of Sciences

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It is the work that is expected to be carried out under the supervision of **Dr. Bhawna Singla.**

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Rishita Mishra

Registration Number- MRUMADN012K220058

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Supervisor

17/12/25

Dr. Bhawna Singla
Assistant Professor
Department of Sciences (Mathematics)
School of Sciences

ABSTRACT

This short synopsis proposal gives an overview of existing tradition method in transportation problem such a NWCM, LCM and mainly Vogel's Approximation Method. There is some limitation in existing Vogel's Approximation Method, so our current purpose of the study is to propose some better change in Vogel's approximation method to deal with the computational complexity and iterations in the method.

This short synopsis comprises the **five sections** namely, Introduction, Literature review, Description of broad area, Objectives of research, Methodology to be adopted and Expected Outcome of Research.

Section one sets a brief introduction of the transportation problem and is divided into two subsection. The **first subsection** titled Mathematical Formulation aims to explain the formula and condition for transportation problem and **second subsection** titled Fundamentals of Vogel's Approximation Method aims to provide brief description of Vogel's approximation method and its methodology.

Section two namely Literature review aims to highlight the main work done by the various author related to transportation problem and mainly Vogel's Approximation Method.

Section three explains the Broad area of research.

Section Four deals with different objectives related to goal of the research.

Section Five explores the Methodology to be adopted for the research.

Section Six discusses the Expected Outcome of Research.

Keywords: -Transportation problem, Vogel's approximation method (VAM), initial feasible solution, modified VAM

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1. Introduction

The primary goal of the transportation problem is to identify the most cost-effective approach to distribute a commodity from multiple supply sources (origins) to various demand (destinations) while minimizing the transportation cost [3] in the network. The key elements of the transportation problem are:

1. Supply at origins: The quantities of commodity available at each source of the network.
2. Demand at destinations: The quantities required at each destination [21].
3. Transportation costs: The cost associated with transporting a unit of the commodity from each origin to each destination. The objective is to allocate resources efficiently so that transportation costs are kept as low as possible, while satisfying the supply and demand constraints at all origins and destinations. This problem can be solved using various methods such as the Northwest Corner Rule [3], Least Cost Method [21], Vogel's Approximation Method [14], and more advanced optimization techniques like linear programming or adaptive solutions when uncertainties are involved.

1.1. Mathematical Formulation

Let's consider that there be m origins i^{th} origin possessing a_i units of certain products, whereas there are n destinations where **m** (number of sources) does not necessarily need to be equal to **n** (number of destinations) with destination j requiring b_j units. The costs of transporting of an item from each of m source to each of n destinations are expressed in terms of shipping hours, or possibly other factors such as fuel consumption and labor [20-22]. Let C_{ij} be the value of transporting one of the products from i^{th} origin to j^{th} destination. X_{ij} be the number/aggregate to be transported from i^{th} source to j^{th} destination. Let's consider that the total supply a_i available at all the origins is equal to the total demand b_j at all the destinations i.e.

$$a_i = b_j \ (i = 1,2,3,...m;\ j=1,2,3,...n)$$

If $a_i \neq bj$ $(i = 1,2,3,4,...m;\ j=1,2,3,...,n)$ some manipulation is required to make

$$a_i = b_j \ (i = 1,2,3,...m;\ j=1,2,3,...n))$$

The problem is to be determining non negative values of X_{ij} satisfying both the availability constraints:

$$\sum_{j=1}^{n} X_{ij} \leq ai$$

As well as the requirement constraints:

$$\sum_{i=1}^{m} X_{ij} \geq b_j \quad \text{for } j= 1, 2, 3,\ldots, n$$

and minimizing the total transportation value involves solving the problem optimally

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$$

The particular Transportation Problem is mentioned to be balanced if

$$a_i = b_j \quad (i = 1,2,3,4,...m;\ j=1,2,3,...n)$$

The Transportation Problem try to calculate values for X_{ij} that satisfy these conditions while optimizing the transportation total cost Z for the problem.

1.2. Fundamentals of Vogel's Approximation Method:-

Vogel's approximation method (VAM) is a heuristic technique used to find an Initial feasible solution to the Transportation problem in operations research [3]. It aims is to reduce the overall Transportation cost by considering the penalty cost, for not using the second least expensive option in each row and column. VAM is particularly valued for its efficiency and effectiveness in yielding solutions that are often close to the optimal [2].

1.3. Explanation of Vogel's Approximation Method

Vogel's approximation method (VAM) [14] operates on the aim of minimizing the transportation cost in each step we minimize the entire cost by choosing the allocation with least penalty in row matrix or column matrix. These are the following steps to describe the working of VAM:-

1. In the transportation problem calculate penalty for each column and row of the given transportation cost matrix by subtracting the smallest cost and the second smallest cost entry in that row matrix or column matrix.
2. Select the highest penalty cost either from the column matrix or row matrix in the cost matrix with Transportation problem.
3. In the selected row matrix or column matrix with the highest penalty opt as much as possible minimum cost value to the cell in the matrix and allocate maximum possible supply and demand cost i.e. min(supply, demand).
4. Cross out the satisfied row matrix or column matrix in the cost matrix of the Transportation problem.
5. Upgrade the penalty costs from the remaining uncrossed rows and columns.
6. Repeat the steps 1-4 until all the supplies and demands are satisfied.

VAM's calculated a solution is generally more aligned with the optimal solution than those obtained by other existing traditional method.

2. Literature Review

The initial formulation of the Transportation problem was introduced in the 1940s with the work of Frank L. Hitchcock [20]. In his 1941 paper, "The Distribution of a Product from Several Sources to Numerous Localities," Hitchcock introduced the cost matrix and developed an algorithm for solving the Transportation problem and T.C. Koopmans [3] developed the optimal allocation theory [25], which focused on finding the most efficient way to allocate resources.

Vogel's Approximation Method [6] was introduced by W. V. Vogel in 1958. The method was designed to provide a better initial solution [15] than the previously used North-West Corner Rule and Least Cost Method, which often resulted in higher initial costs and required more iteration to reach the optimal solution. VAM was developed as part of a broader effort to find more efficient algorithms for finding linear programming problems, particularly those with large datasets.

Ahmed Atallah Alsaraireh (2023) discovered Summation And Ratio Method [2] that simplifies the calculation of total transportation cost for each row and column and then analysis the optimal cell cost by cross out the smallest row ratio with the largest column ratio in the problem. If the transportation problem is unbalanced make it balanced and then calculate the total transportation cost for each row and column, and then finding the suitable cell to be filled in the given line with the ratios. Repeat all these steps until all the demands and supplies are satisfied. In this paper various quantitative example are taken to solve and compared the result with various classical method such as NWCM, LCM, VAM and MODI methods.

LadjiKané et al. in 2022 presents Solution of Fully Fuzzy Transportation problems [19] in which the main objective of the paper is to introduce substitutive solution approach in attaining the fuzzy optimal solution to a fully fuzzy Transportation problem with minimum uncertainty. In this paper the fully fuzzy transportation problem is altered into equivalent transportation problem involving interval numbers.

Amulu Priya S et al. (2022) explored Vogel's approximation method and discovered New Vogel's Approximation Method (NVAM) to Better Feasible Solution [20]. The traditional VAM method is commonly used to find a feasible solution with some limitations in the penalties calculation, mainly when the smallest costs in rows or columns have equal value while New Vogel's Approximation Method (NVAM) is focused on these limitations of VAM by defining penalties as a ratio between the two smallest costs, instead of simply subtracting them as in VAM. This method ensures a refined allocation of values based on penalties calculated from the ratio. This study concludes that NVAM is a more reliable method for calculating IBFS of the transportation problems. This method not only improves the feasibility and accuracy of solutions but also often yields results equal to or close to the optimal solution of the Transportation problem.

In June 2021 B. Mallia et al. [21] introduced Transportation Problem's Fundamental in which this paper presents in-depth exploration of Transportation problems, which are a subset of Linear programming (LP). The paper introduces various forms of Transportation problems, including bottleneck, minimax, maximin, time minimization, and volume minimization problems, focusing on methods to achieve optimal transportation solutions. A key method discussed is the Modified Distribution (MODI) method, which aims to find the optimal solution after finding the Initial basic feasible solution (BFS) through various existing methods like the Northwest Corner Rule, Least Cost Method (LCM), and Vogel's Approximation Method (VAM). This work culminates in introducing applications like the enabled transportation problem, which adds conditions on the amount of goods that can be transported between sources and destinations.

Tolga Bektasü et al. (2018) introduced Operational Research in Green Freight Transportation [5] which plays a pivotal role in reducing the harmful environmental effects caused by freight transportation. By creating mathematical models and optimization techniques, OR helps make transportation systems more environmentally friendly and efficient. This is especially important in areas like road transport and maritime shipping, where better planning and resource management can significantly cut down on fuel consumption, emissions, and other negative

impacts on the environment or aims to create solutions that reduce costs and carbon emissions simultaneously, known as "win-win" solutions.

M. S. R. Shaikh et al. (2018) explored an Improved Algorithm for Optimal Solution [24]. In this research paper the traditional methods such as the Least cost method (LCM) and North-West Corner method (NWCM) is compared with the new method and demonstrates equal or great performance in several cases study. This paper focuses on improving the efficiency of IBFS in transportation problem, where the main thing is reducing the total cost of transporting goods from different sources to destinations. The proposed new method's algorithm introduces a step-by-step penalty calculation based approach to optimize the transportation cost in operation research through a. In the beginning, the penalties are calculating by determining the difference between the lowest cost and next-lowest costs in each row or column of the cost matrix. Then, there is an iteration process for selecting minimum costs for the cost matrix which is based on penalties and minimizes the supply or demand according to requirements. This procedure repeats between these steps until all supplies and demands are allocated and satisfied in the transportation network. The proposed improved new algorithm is more accurate than traditional existing methods like NWCM and LCM, and provides a reliable, accurate and easy approach for solving transportation problems. This paper suggest that this new method can be used as an alternative to traditional methods, especially when quick and accurate results are required.

In 2017 Martina Hlatká1 et al. discussed transport-logistics processes of a manufacturing company by comparing two logistic transportation techniques. These optimization techniques are a heuristic for building transport routes that is called Vogel Approximation Method (VAM) and another is adapted to logistics to minimize transport costs called Modified Vogel Approximation Method (VAM). Vogel Approximation Method (VAM) is used to find routes and shortened travel distance, leading to reduced costs while Modified Vogel's Approximation method find greater optimization then previous traditional method. This research concluded that mathematical optimization methods in logistics provides tangible improvements. Both the methods effectively provides shortened delivery routes and reduced operational costs. But the modified VAM

provides the most effective solution, by reduction in the total distance and annual transport costs in the logistics.

In 2017 Eghbal Hosseini focused on three new Methods to find Initial basic feasible solution [15] which affected many research scholars in optimization because of their relevance in various area of practical application. Therefore, solving of these problems initially finding Initial basic feasible solution for them would be significant. This paper proposed a novel algorithm that efficiently determines a superior Initial basic feasible solution to starts the simplex method for transportation problems. The new proposed methods, and as well as some previous algorithms used to solve test and created problems in various sizes in all given formulation of the transportation problem. For the future research in transportation problem area, these generated formulations, comparisons and also MATLAB codes of the Vogel algorithm, can be valuable. Ultimately, a new modified method, better than existing algorithm, which can propose optimal solution will be initial challenge of the transportation problem networks. So, in this paper Modification and advancement of the traditional method is beneficial concept for proposing a valuable algorithm to find feasible and optimal solution for the problems.

Mollah Mesbahuddin Ahmed et al. (2016) introduced a new approach to solve Transportation problems [1]. The study of this research paper concluded that it has different methodology to find IBFS of the transportation problem. In this paper the author introduces Allocation Table Method (ATM), which is a modified algorithm focused on improving the IBFS of the problem. The review of proposed algorithm of the transportation problem showcases the continuous innovation focused on improving the accuracy of IBFS. The ATM significantly contributes to improving the efficiency for logistics and transportation networks by ensuring minimum costs near optimal solutions in operation research.

E Ellaimony et al. (2015) introduced a dynamic programming approach to solve a class of bi-criteria multistage transportation problem [10] that focused on the application of dynamic

programming to optimize transportation problems with multiple objectives, and the result underscores the development of algorithms for bi-criteria and multi-stage transportation problems, with various forms of bi-criteria multistage transportation problems, formulating four distinct problem classes (BMTP1–BMTP4) based on specific restrictions and problem structures at transitional stages. Dynamic programming emerging as an effective method for optimizing such problems by reducing complex multi-stage processes to simpler single-stage problems. Dynamic programming breaks large problems into smaller sub problems (stages), optimizing decisions step-by-step. The technique is particularly useful for solving shortest-route problems in transportation networks and finding non-dominated solutions in bi-criteria problems.

Utpal Kanti Das et al. (2014) initially explore traditional existing Vogel's Approximation Method that can provide better initial feasible solutions to reach optimality and leads to less iterations by using penalty to make allocations strategically then other traditional methods such as NWC method and least cost method (LCM). But there are some limitation on VAM when two or three penalty are same in the calculation so the produced result is less in optimal initial basic feasible solution. After that (Khan & Uddin, 2014) introduced Logical Development of Vogel's Approximation Method (LD-VAM) [18] that enhances computational efficiency by removing complexity in which penalty ties are resolved logically and produces high quality IBFS and closer to optimal**.**

Arindam Chaudhuri et al. (2013) explored various studies and performed a Comparative Study under Probabilistic and Fuzzy Uncertainties [7]. According to the study of proposed Fuzzy models it is clear that it provides more flexibility when dealing with imprecise or incomplete data of the problem, while probabilistic models are more robust in scenarios with clear, quantifiable uncertainty. This study is important for logistics, supply chain management, and decision-makers who need to select appropriate models to handle uncertainty in transportation problems, based on the nature and type of uncertainty they are dealing with. In the proposed method, the probabilistic and fuzzy approaches provide auxiliary tools for dealing with uncertainty in transportation problems. Fuzzy logic provides flexibility in dealing with vague

information, while Probabilistic models are used for the situations with quantifiable randomness. The probability distributions requirement is the failure of probabilistic models and the failure of fuzzy models is that it can sometimes incorporate subjectivity since they depend on linguistic expressions. Hybrid models are important as it can be calculative, demanding and approaching advanced techniques to obtain the strengths of both models. In this paper the method applies dynamic programming (DP) to obtain the shortest routes for transportation while optimizing two goals: minimizing transportation cost and reducing degeneration. This study show that how the transformation of a complicated multistage problem into a more straightforward single-stage problem using dynamic programming can enhance efficiency.

In 2011 Korukoğlu et al. [19] explored the Vogel's Approximation method and developed an improved form of that method. According to authors, after review of various research paper, there are many limitations in existing VAM, mainly when it comes to large-scale transportation problem networks. So the Improved Vogel's Approximation Method (IVAM) introduces the concept of the total opportunity cost (TOC), which involves adding the rows and columns opportunity costs from the matrix table. The total opportunity cost (TOC) matrix table provides better result for penalty calculation and allocation entry decisions in the table. In IVAM, three largest penalty costs are considered from the starting, and by comparing the lowest transportation costs in these rows or columns from the matrix allocations are made for further calculation. IVAM provides more accurate calculation for solving large transportation problem network. Improved Vogel's Approximation Method (IVAM) reduces the complexity in computation and number of iterations in the transportation matrix effectively. This study has an important enhancement to transportation network by developing a method that will be more accurate for complex and large-scale transportation problems, making it an important for optimizing transportation costs.

3. Description of Broad Area

The large area of research for Vogel's Approximation Method provides several elements, like supply chain management [24], transportation problem-solving [18], and computational optimization techniques. This involves methods for effectively allocating resources from multiple sources to demand in a way to reduce cost, time and some other relevant criteria [25]. VAM provides a suitable balance between computational efficiency and solution quality of the problem, new research is evolving continuously to improve its performance and adapt to modern complexities. Modify Vogel's approximation method [14] not only solves a single-objective problem i.e. cost minimization but also optimizes multi objective problems like delivery time and carbon emissions. Addressing sustainability concerns, instead of solving just a cost minimization, the method should also handle sustainability and service-based objectives.

The key points for broader area of research are optimization of distribution networks, Cost minimization in supply chains, Vehicle routing and logistics planning, Real-time optimization in dynamic supply chains, Demand forecasting and inventory management, Comparing Vogel's Approximation Method with other methods of optimization [22] like the Northwest Corner Method and Least Cost Method, Real-time adaptability and handling dynamic environments .

4. Objectives of the Study

The primary objective of the following study is to develop new advancement in Vogel's Approximation Method [14] for solving transportation problems, fastening on enhancing its effectiveness in finding optimal result [2] which improves the quality of the initial solution. The motive is to minimize the overall transportation cost and computational time, making the method more effective for large-scale and complex logistics problems.

- Study and Review existing traditional methods to find the better basic feasible solution [18] and transportation cost of the network.
- Propose and Implement Modifications to VAM that incorporate adaptive strategies, similar as dynamic cost adaptation, penalty mechanisms, and real-time data integration, to improve the accuracy and efficiency of the method [24].

- To Illustrate the Practical relation of the modified VAM in real-world transportation network that showing it's potential to effectively optimize logistics and other supply chain management.
- To Enhance Solution Quality in Specific network for certain modifications that may give better results in asymmetric transportation problem.
- To Integrate with Modern Computational method that Modified VAM approaches can be made more compatible with algorithmic implementations for better result.

5. Methodology to be Adopted

The basic concept of exploration was directed towards the modification in Vogel's Approximation method [7] with adaptive result in transportation networks.

- Review with existing methods [2]: Developing a real-time adaption of VAM with review of existing methods that will adjust its calculations based on supply and demand of the problem.
- Comparative study [22]: Comparison with other existing traditional transportation methods like North-West Corner Rule (NWCR) and Least Cost Method (LCM).
- Formulation for enhance Penalty Calculation [12]: Exploring penalty cost (difference between required supply and demand) calculations that based on the supply and demand, resulting to more cost-effective initial allocations in the transportation problem.
- Flexibility on Calculation complexity Scale: Advancing VAM to handle large-scale networks problem with complex calculation, including multiple forms of transportation and different cost structures with flexibility in calculation.
- Case study with generalized illustration: Apply the modified VAM and other existing methods on same large scale transportation problem for case study.

6. Expected Outcome of the Research

While pursuing PhD, our main perspective is to develop some modification in existing Vogel's approximation method for some specific large scale transportation problem in operation research.

The expected outcome of the research are as follows:-

Improved Initial feasible solution: - The modification in VAM is expected to provide more robust and capable of producing cost effective and better initial feasible solution in transportation problem in comparison to traditional VAM.

Minimization in total transportation cost: - The proposed modified VAM anticipated to provide relevant advancement in calculation and minimize total transportation cost that is beneficiary for logistic and other supply demand management.

Practical Application: - In real world this method handle complex environment and increase the practical applicability of the transportation network.

Computational Efficiency:- The advancement in Vogel's approximation Method provides a framework which improve the computational efficiency of the network through handling the complexity such as unbalanced problem, degeneracy etc. effectively

Reduction in iteration: - The proposed modified VAM is expected to generate the total transportation cost with less number of iteration that reduce the complexity of the transportation network problem.

Encouraging Industrial and Academic advancement:- The advancement of this result is expected to be valuable and efficient for Academic research and industrial advancement.

Versatility in handling complex cases:- The output of this result is flexible in handling special cases which can be complex in logistics and supply chain management.

Overall, this research will effectively advances the use of Modified Vogel's Approximation Method in transportation networks.

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Researcher: Rishta Mishra

Registration Number: MRUMADN012K 22058

Supervisor: Dr. Bhawna Singla

Department: Sciences (Mathematics)

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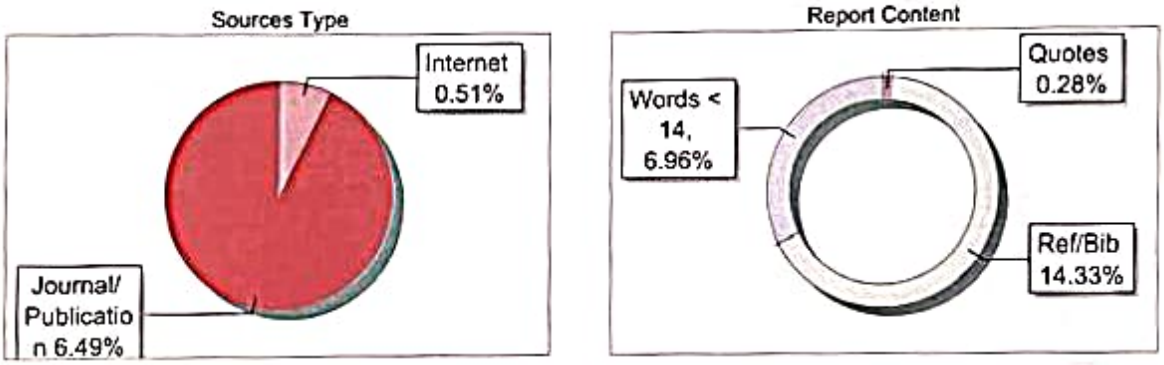

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ADAPTIVE SOLUTIONS FOR OPTIMIZING TRANSPORTATION NETWORKS

SHORT SYNOPSIS

by

Rishita Mishra

Registration No. – MRUMADN012K220058

Under the supervision of

Dr. Bhawna Singla

(Assistant Professor)

MANAV RACHNA UNIVERSITY

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ABSTRACT

This short synopsis proposal gives an overview of existing tradition method in transportation problem such a NWCM, LCM and mainly Vogel's Approximation Method. There is some limitation in existing Vogel's Approximation Method, so our current purpose of the study is to propose some better change in Vogel's approximation method to deal with the computational complexity and iterations in the method.

This short synopsis comprises the **five sections** namely, Introduction, Literature review, Description of broad area, Objectives of research, Methodology to be adopted and Expected Outcome of Research.

Section one sets a brief introduction of the transportation problem and is divided into two subsection. The **first subsection** titled Mathematical Formulation aims to explain the formula and condition for transportation problem and **second subsection** titled Fundamentals of Vogel's Approximation Method aims to provide brief description of Vogel's approximation method and its methodology.

Section two namely Literature review aims to highlight the main work done by the various author related to transportation problem and mainly Vogel's Approximation Method.

Section three explains the Broad area of research.

Section Four deals with different objectives related to goal of the research.

Section Five explores the Methodology to be adopted for the research.

Section Six discusses the Expected Outcome of Research.

Keywords: -Transportation problem, Vogel's approximation method (VAM), initial feasible solution, modified VAM

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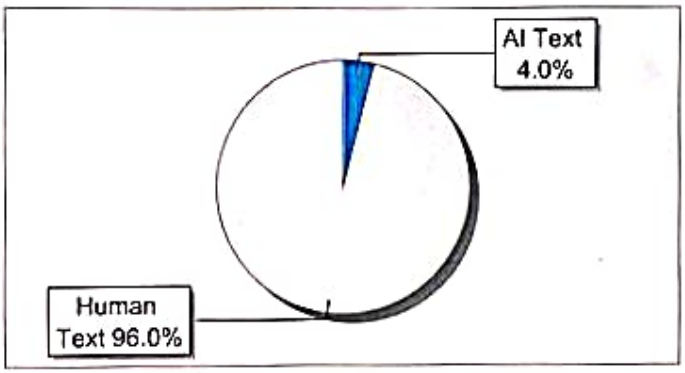

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